SOME INDIAN FOREST FUNGI.

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CRYPTOGAMIC BOTANIST TO THE GOVERNMENT OF INDIA.

To one interested in the lowly mushrooms and moulds India, at first, often comes as a disappointment. Before experience one pictures all tropical countries as teeming with rare and beautiful forms of plant life, and there is no hint that the fungi are to be, even partially, excluded from the scene. The reality is in many cases a cultivated plain or a paddy swamp extending as far as the eye can reach. Of fungi there are few, and these often familiar crop pests. There are no moist woodlands as in Europe. The trees are mango groves, or palms clustered around the villages, or avenues of shade-trees bordering the roads. Even the jungle is too often dry scrub, the last place in which fungi could flourish. The odour of decay is absent, fallen leaves are scarce, decaying branches—most loved of fungi—are almost unknown. For in India life is too hard to allow of anything that burns being left to waste. There are, too, few old fences, or grassy slopes moist from the shade of trees, or any, except rarely, of those other favoured spots to which the mycologist must look to gather his harvest. The reasons for this are simple. The population is very dense, with consequently a close cultivation of the land. Added to this is, in the parts to which I refer, a climate too dry for the greater part of the year and often too heavily flooded in the rains to permit of that gradual return to the soil of organic matter in which the fungi find their most favourable conditions of development. I can hardly imagine anything more unsuitable looked at from this point of view than the plains of Northern India from the Punjab to Behar or the bare uplands of the Deccan.

But there are great areas in the continent, often away from the beaten track, in which all these conditions are changed. The region at the base of the Himalaya and the slopes of the hills themselves as high as the forest vegetation goes, much of South

India, both the moister mountainous parts and the tracts along the coast, all of the Ghats, much of Lower Bengal and Assam are rich in fungi. In the forests of these regions, amongst which are some of the most important in India, there is a vast amount of material awaiting collection, and there are few in India with such opportunities of helping a much-neglected branch of science as the officers of the Forest Department in these places.

In the following notes reference is made to parasitic fungi only. These, though independent of decaying plant-food, getting their nutriment as they do from the living tissues, find in the forest conditions of moisture and shade most favourable to their development. So far as my experience goes the parasitic forest fungi enormously exceed those of the open country in number, though their economic importance is less evident.

That the study of fungi is a necessary branch of forest science need scarcely be remarked. Their importance in forest economy will be evident to any one at all acquainted with the work of German mycologists. The results obtained in that country are largely applicable to the rest of Europe. In India, however, we can draw only to a slight extent on experience elsewhere, and there is, as yet, little to offer in its place. Even where the parasites are identical the trees on which they live are usually distinct, and it is at least possible that the mode of action differs with the different hosts. In the well-known conifer parasite, *Fomes annosus*, the extension by *rhizomorphs* is a characteristic feature of its attacks on the deodar in the Himalaya, while these organs have not been described for the same fungus in Europe, either because they do not exist or, as Prof. Mayr believes, because they have escaped attention. In any case they can hardly be as well marked as in India. But it is probable that the majority of our parasites are entirely different to those of Europe and America, and the fact that a larger number of new forms have not been brought to light is only an evidence of our want of knowledge of the subject.

I have received several specimen of parasitic fungi on forest trees and shrubs within the past two or three years, mostly

through the kindness of Forest Officers. Some of these have been the cause of very considerable damage, as in the cases of *Fomes annosus* on deodar, *Fomes Pappianus* on babul, *Trametes Pini* on *Pinus excelsa*, the *Trichosporium* on casuarina, &c. Others, such as the rust fungi of conifers and ephedra and of the barberries, are of less account. But even the latter are often of great interest from their indirect influence on the diseases of cultivated crops or important industries such as tea and coffee planting. For instance rust on cereals has often been attributed to the fungi of the Himalayan forests, and there is no doubt that this view has influenced considerably those in India who have given thought to these diseases. The *Rosellinias*, fungi which arise in the decaying stumps of many trees, have proved a serious trouble in tea and coffee cultivation, giving rise to constantly expanding patches of what is known as "stump rot" in many estates, within which every bush is destroyed. If taken early they can be checked, and their prevention by a proper treatment of the tree stumps seems not beyond the bounds of possibility. The forester who can devise a satisfactory and cheap method of destroying stumps after felling by burning or blasting, or who can show how to preserve a stump from rotting in the mass, will confer a real benefit on planters in India. From a disease of this nature, combined with another parasitic fungus, the cultivation of pepper on a large scale in Mysore, which is otherwise full of promise, has been prevented Again, there is the remarkable group of host-changing fungi—the *Uredinea* or rusts—about whose life-history the late Dr. Barclay, has told us so much. Large numbers of these are known in India, in one stage only, and the other stages are probably passed on different plants. Some of these in the forests may be found to have a direct bearing on crop diseases. And leaving out of consideration altogether the economic aspect, the forests are full of interesting forms, capable of throwing light on obscure questions as the rhododendron rusts perhaps do in one direction, or of affording valuable materials for study. Our collections of Indian fungi are as yet very meagre. We do not even know the identity of the species which produce the phosphorescence noticeable

in the forests in some places, nor completely the identity of the edible forms of India. If, then, Forest Officers whose locality offers them the opportunity can be induced to collect and study the fungi of their districts, both those injurious to trees and those otherwise of interest, a great advance in our knowledge of a little known subject will almost certainly be the result.

TRICHOSPORIUM DISEASE OF CASUARINA.

The Casuarina plantations on the sand dunes of the East Coast are subject to several diseases. Some of these are due to insect pests and have been described in this Journal by Mr. E. P. Stebbing (*Indian Forester*, September 1903). One, however, which I saw in the Chatrapur plantations with Mr. C. Fischer, I. F. S., in August 1904, is of a fungal character, and being one of those slow and steadily progressing diseases which may eventually become a serious matter, requires more than passing notice.

Attention appears to have been first called to the fungus attack during Mr. Stebbing's visit in July 1903. Amongst the dead trees, of which there were a number in the plantation, some were found with the bark raised up into great blisters, and eventually ruptured by the formation of a black powdery substance consisting of myriads of spores of a fungus. Enough of this powder was easily collected to fill a small box. It appeared on very few trees, however, and the idea that it was connected with the disease was for a time abandoned by Mr. Fischer. When we walked through the plantation only two or three instances were found, and the majority of the dead trees, of which several hundreds were seen, had perfectly normal bark with no sign of the presence of any parasite.

The trees died out in patches, of which two or three large and several smaller ones occur within the Agusti Nowgam plantation. No reason could be given why some parts of this plantation were failing, while the rest flourished. But the examination of specimens collected during my visit and of others subsequently sent sufficiently explained the matter. A parasitic fungus was

found within the central wood, which there can be little doubt is the cause of the disease. It is, curiously enough, apparently identical with that first found in the bark, some minor differences in structure and measurements being probably due to the different conditions of life passed buried in the wood, and that passed in the cambium where access to the outside world becomes possible by the rupture of the bark. Why it should sometimes remain internal and sometimes break out on the surface is not clear.

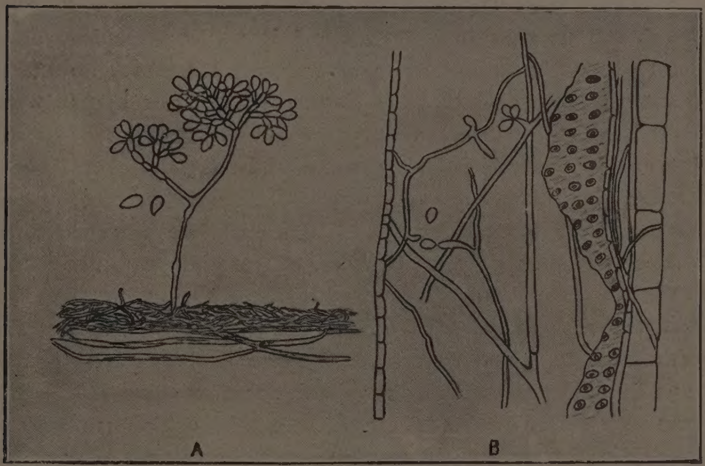

FIG. 1.—TRICHOSPORIUM ON CASUARINA; *a*, BARK FORM; *b*, INTERNAL FORM WITHIN A WOOD VESSEL.

In the earlier stages the trees look sound enough, even when the collar is exposed, except that many of the twigs are dead and clusters of withered needles remain attached to them, the whole appearance suggesting water-logging or drought. The extension of the dead patch from which the specimens were taken in a centrifugal manner up a sharp slope of the sand, which is here very deep, and the healthy state of the adjoining trees put these possibilities, however, out of the question.

The internal fungus was found in the specimens examined in a part or the whole of the wood of the collar, extending six or eight inches below the surface of the soil and a few inches above. It occupies the centre of the wood, reaching in one or two places to the vicinity of the cortex, but elsewhere separated from the exterior by an inch or more of sound tissue. It is not visible to the naked eye, but in some cases is accompanied by a discolouration of the wood, visible on section. In some of the specimens it was impossible to determine if the fungus were present or not without microscopical examination. The wood of many of the lateral roots is also discoloured, and where they enter the tap root their passage through the exterior tissues is sometimes distinctly visible as dark streaks. These lateral roots as well as the diseased patch of collar wood contain fungus hyphæ, while the rest of the tissues are quite free from them.

The hyphæ lie within the vessels and cells, boring their way through any intervening cell-walls. Both brown and colourless ones, belonging to the same mycelium, occur, in some parts the brown predominating, while in others only colourless can be found. In the smaller roots brown hyphæ are rare. On lateral branches from the main filaments spores are borne at or near the apex in small clusters. They are at first more or less spherical and colourless, but later become oval and brown, falling easily and lying within the vessels. Their utility in this position can be but slight, for none were found in the smaller roots and decay of the collar sufficient to liberate the spores would probably take some years. Unless the fungus also forms spores in the soil, its propagation is likely, so far as the subterranean form of attack is concerned, to be mainly vegetative by means of a soil mycelium extending from root to root through the ground. The centrifugal progress of the disease from a few centres lends support to this view.

The destruction of the wood is not considerable. All the contents of the cells invaded by the hyphae are destroyed and a brown residue fills those which have had living contents, such as the parenchyma, giving rise to the discoloured appearance of

the diseased tissue sometimes observed. Lignified tissues are but slightly attacked, and there is no change apparent in the walls of the fibres until a late stage. The effect of the fungus on the tree is greater than would appear warranted by the mere destruction of the living contents of the cells, and the physical result of blocking of the vessels with hyphæ. It is probable that the death of the trees is largely due to ferment production, or the formation of some poisonous substance thrown into the sap, as happens in so many cases of the sort. In the sugarcane red-rot for example the fungus *Colletotrichum falcatum* is often confined

FIG. 2.—CASUARINA STEM ATTACKED BY TRICHOSPORIUM.

to one or a few internodes near the base of the cane, but the total crystallisable sugar is greatly diminished by the action of a sugar-inverting ferment, formed by the fungus and acting on the sugar-containing sap. The greater part of the damage is apparently due to this ferment.

The bark-rupturing fungus, first observed, produces far more striking effects.

The bark is lifted from the cambium along the trunk into great blisters by the formation here of a layer of densely woven hyphæ, which produce spores in such abundance that the black powder composed of them is sometimes a quarter of an inch in depth. Later on these blisters rupture, raising the bark in loose sheets and exposing the spores. The tissues under the spore-producing layer are invaded everywhere by hyphæ, which are colourless in the outer cells and sometimes brown deeper in. Microscopically no difference can be observed in the mycelium of this from that above described, except that the portion from which the sporophores arise is invariably colourless. The spores in this case are also rather larger and their colour deeper brown. They are borne on hyphæ of variable length and often branched, each branch bearing a cluster of spores near its tip on the main axis or on short thick branches of the secondary or tertiary order. Branched sporophores of this type were not observed in the internal form, but the latter was much more difficult of examination and the spores were very rarely found fixed *in situ*.

In the absence or rarity of the external mode of fructification and from the nature of the diseased patches, it is probable that the fungus extends through the upper layers of the soil from root to root. Hence the only suggestion for treatment which can be made at present is to remove as early as possible all diseased trees to prevent the bark-destroying form, which appears to be of late appearance, from developing. The collar and main roots should also be removed in trees near the margin of the diseased patches as far as possible. Trenching might prove effective in checking progress, but further observations and trials are necessary before the efficacy of this can be established. After clearing it will be unsafe to replant for some two years or so as the fungus is likely to persist for some time in the smaller roots which are left.

This fungus possesses many points of resemblance in the bark form to another tree-destroying fungus found by Mr. Massee of Kew on mulberry trees sent him from Changa Manga, in the

Punjab. The mulberry fungus which Mr. Massee named *Trichosporium aterrimum* is also made manifest by a rupture of the bark from the cambium in which its spores are formed. The minute structure, however, differs in some respects, particularly the size of the hyphæ and the mode of origin of the spores, though the specimen which I examined from the Forest School Museum was not entirely satisfactory for determining the minute characters of the fungus. In any case the name *Trichosporium aterrimum* cannot stand since it has already been used by Saccardo for a species of Corda's (*Sylloge fungorum IV*, p. 289). I have named the Casuarina fungus *Trichosporium vesiculosum* n. sp. and the diagnosis is as follows :—

Trichosporium vesiculosum n. sp.—Hyphæ brown or colourless within the tissues or forming colourless cushions in the cambium; fertile hyphæ colourless, 1½ to 2 micro-millimeters in diameter, bearing clusters of spores inserted at or near the tip on the thickened end of the main axis or of secondary and tertiary branches, several on each branch; spores sessile, ovoid, brown, in the mass black, forming a dense layer in the cambium fewer in the tissues, 5—8 × 4½—6 for the external and 6 × 4½ micro-millimeters in diameter for the internal.

Parasitic on *Casuarina equisetifolia*, which it kills—Chatrapur, Ganjam, India.

Allied to *Trichosporium aterrimum*—Massee not Saccardo.

A number of exceptionally interesting fungi of the order Uredineæ, more commonly called rusts, occur in the Himalayan forests. They are perhaps the best known of all Indian fungi from the work of the late Dr. Barclay of the Indian Medical Service, who in the short space of six years, from 1886 to 1891, published over twenty papers dealing with these fungi, and described 109 species, of which 72 were new to science. It has since become clear that he only touched on the fringe of a vast subject. Almost all his species were collected in the immediate neighbourhood of Simla, and as we pass along the range the variation of the fungus flora keeps pace or perhaps exceeds that of the general flora. The Mussoorie and Jaunsar barberries, for instance, bear an entirely

different Æcidium from that on the Simla ones. A few scanty observations around Darjeeling have convinced me that the rusts of the Sikkim Himalaya differ widely from those further west. I believe that the Himalayan range is one of the richest regions of the globe in the members of this group. They have, however, almost escaped the attention of collectors. The Sikkim species are practically untouched, and our knowledge elsewhere, excluding Simla, is confined to the most conspicuous forms in a few easily accessible spots.

It is necessary, in order to render intelligible the following notes, to deal briefly with the general characters and often complicated life-history found in the order. All are parasitic, and the most destructive of known fungus diseases of cultivated plants are caused by the members of this group. Such are the rusts of cereals, annually responsible for the loss of millions in the grain-producing countries, the coffee leaf disease, which destroyed the planting industry of Ceylon some forty years ago, the linseed rust, exceedingly destructive in India, and many others. Most are confined to a single species or to a few closely allied species of host; the host being almost invariably a flowering plant. Unlike the fungi with which we are chiefly familiar, such as the mushrooms and moulds, which can get their food from a variety of substances, the rusts require food of a definite composition, and usually find it only in one or a few living plants. It speaks volumes for our ignorance of the true composition of living plant substance that their artificial cultivation has never yet been accomplished. But the most remarkable phenomenon in the group is that known as "heterœcism" or the passing of different stages of the life-history on different and often widely separated host-plants. It is an eccentricity entirely comparable to that of the parasite of malarial fever in man, which, as we know, is obliged to pass a portion of its life in the body of the mosquito. Within recent years science has had its interest awakened in this class of parasite, and we may expect to find other diseases due to the development of so objectionable a character, long known however in the fungi and some lower animals, added to dengue, sleeping sickness, yellow

fever, malaria, &c. Another phenomenon exhibited by the rusts which may also have its counterpart in the parasites of man is that of "specialisation." Some of the species which attack several hosts have got split up into races without any external difference but each confined to its own variety of host and unable, without some difficulty, to attack the hosts of the others. It is as if we should imagine that plague, to which Europeans are now comparatively immune, but which once ravaged Europe (if indeed the Black Death were plague), had got from long restriction to the East developed into a race no longer capable of readily attacking whites, while the parasite in Europe had gradually died out completely. The black rust of cereals attacks both wheat and oats, and the forms are absolutely alike, and beyond doubt are of one origin; yet that on wheat cannot pass to oats, in India at any rate, and as the race on oats has not yet been introduced here, we commonly have, as in Dehra Dun, the remarkable sight of fields of wheat severely attacked with black rust alongside oat fields where not a trace of the disease can be found.

In the life-history four stages are usually recognised. These may all be passed on the same plant or some may be passed on one plant and the others on another. They are known as the æcidial, uredo, teleuto and sporidial stages.

The æcidial stage, or Æcidium, consists of a little plant body or mycelium formed of thread-like cells running between the cells of the host plant and obtaining food from them by means of little suckers pushed through their walls. It is usually found infesting leaves, but sometimes occurs on shoots, flowers and fruit as well. It is marked by the formation, as reproductive bodies, of æcidiospores, usually minute, yellow, spiny bodies enclosed in a cup-like receptacle, of which the cluster cups of the barberry are a more or less familiar example. With these a second spore-form, the "spermatia," whose meaning is not clear, is often found. On germination the æcidiospores usually give rise to the uredo stage.

The uredo stage also consists of a mycelium much like the first, but it gives rise to uredospores which differ in colour, size, shape or

some other character from the æcidiospores. They are formed under the epidermis and are without the little cup-like receptable.

The teleuto stage arises from the same mycelium usually as the last stage, and the two together may therefore be taken as forming one stage only. Teleutospores are formed usually after the uredospore production has finished, but sometimes amongst the latter. Unlike the two preceding, the teleutospore is often composed of more than one cell, and instead of being able to germinate immediately it is frequently a "resting-spore" requiring a lapse of several months from its formation before it germinates.

The sporidial stage results from the germination of the teleutospore. Instead of a mycelium being formed within the plant, a short projection grows out from the teleutospore into the air, and on this a few small spores, the "sporidia," are produced. On germination the sporidia give rise immediately to the Æcidium again.

Now the remarkable fact remains that the æcidiospores on germination are often unable to produce the next stage unless they happen to fall on a different plant to that on which they were borne. Thus the barberry cluster-cup spores cannot attack the barberry itself, but if they come into contact with wheat, barley, oats, etc., they complete their development by giving rise to a mycelium within these plants, eventually bearing uredo and teleutospores and causing the destructive black rust of cereals. Similarly the sporidia resulting from these teleutospores cannot infect a cereal plant, but only a barberry. Just as a malarial parasite in the blood of man must die with its life but half completed unless a mosquito should suck it up, so the sporidia are obliged, in order to complete their cycle, to come into contact with a barberry bush. But as it appears probable that the malarial parasite can live in one stage for many years and induce ague in man years after exposure to mosquito bites has ceased, so also it is certain that the uredo stage of some rusts can be reproduced for years without the intervention of the other stages.

So much being clear, the description of some species which I have received chiefly through the kindness of Forest Officers can be proceeded with.

CHRYSOMYXA HIMALENSE, BARCLAY.

In two papers in the "Scientific Memoirs by Medical Officers of the Army of India," in 1890 and 1891, Barclay described some Uredineæ on Himalayan species of rhododendron, and discussed their relationships, which were rather puzzling.

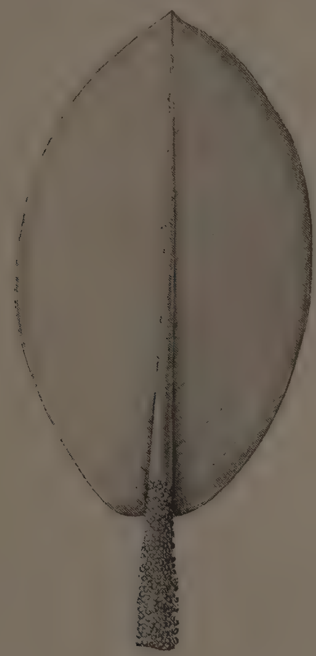

FIG. 3.—CHRYSOMYXA HIMALENSE ON RHODODENDRON CAMPANULATUM.

Around Simla a teleutospore form, which Barclay named Chrysomyxa himalense, is extremely conspicuous on Rhododendron arboreum. Comparing it with its European relative Chrysomyxa Rhododendri, D. C., Barclay sought for its æcidial stage on Pinus excelsa and on Picea Morinda. In Europe the Æcidium of the Rhododendron Chrysomyxa occurs on Picea

excelsa. In India, however, Barclay could get no experimental evidence that his Chrysomyxa was connected with any conifer.

Later on he obtained an Æcidium on Rhododendron campanulatum and a Uredo on R. lepidotum, and the possibility immediately presented itself that the three stages of his Chrysomyxa were passed on the rhododendrons without the intervention of any other plant.

In specimens received from Mr. Hole, I. F. S., from Jaunsar in 1904, the teleuto stage of Chrysomyxa himalense was found by me on Rhododendron campanulatum.

Sir G. Watt also stated in a footnote to his Review of Dr. Barclay's works published in the 'Agricultural Ledger' in 1896 that he found an Æcidium on R. lepidotum which Dr. Barclay declared solved the mystery of these fungi. This it could only have done by proving identical with that on R. campanulatum. Hence we have an æcidial and a teleuto form co-existing on Rhododendron campanulatum, and probably the same Æcidium and a uredo form co-existing on R. lepidotum. The possibility suggested by Barclay that this fungus passes through all its stages on the rhododendrons therefore becomes a probability, and the theoretical interest of this is considerable.

The origin of the remarkable power of changing hosts ("heterœcism"), such as is found for instance in the case of the malarial parasite and in many rust fungi, has naturally given rise to much speculation. Anything throwing light on it is therefore of value. Some have supposed that it is capable of explanation on the descent theory, the parasite having affected the two different hosts from the time of their common ancestor. In the case of the mosquito and man this takes us very far back indeed, and for the rust fungi we should have to look even farther. Others suppose that the parasite originally attacked both hosts and completed its development on each, subsequently losing one portion of its stages on one host and the remainder on the other. But the most probable view appears to be that which considers that the parasite was originally confined to one of the two hosts, and only later, by a sudden adaptation, became capable of passing to the other.

It so happens that European rhododendrons bear, as already mentioned, a fungus, Chrysomyxa Rhododendri, which has its æcidial stage on the spruce, Picea excelsa. The spruce also bears the teleuto form of a second fungus, Chrysomyxa abietis. The two are sufficiently alike to suggest a common origin. Any evidence that the rhododendron species was originally confined to one host will therefore throw some light on the development of heterœcism in this case. It may either have been at first confined to the spruce and then have passed to the rhododendrons in its uredo-teleuto stage, or at first living on the rhododendrons have then emigrated to the spruce in its æcidial stage. Now, though the fungus on Himalayan rhododendrons is unlike that on the European ones in many respects, still it is not unreasonable to

FIG. 4.—GYMNOSPORANGIUM CUNNINGHAMIANUM, ÆCIDIUM FORM ON PYRUS PASHIA.

consider that it also is of common origin with the latter. It would then strongly support the second of these views. In the Himalaya at least, it is now probable that the rhododendron Chrysomyxa was primitively, as at present, confined to the rhododendrons.

We may then suppose that in its passage westward it developed Chrysomyxa Rhododendri by the transfer of its Æcidium to the spruce. From this Æcidium a teleuto form arose on the spruce, giving rise to Chrysomyxa abietis. Hence a competition ensued on the spruce between the Æcidia of Chrysomyxa Rhododendri and of Chrysomyxa abietis, and, as Barclay has pointed out, in such a case the heterœcious form is the more likely to succeed. So the Æcidium of Chrysomyxa abietis was lost. The German mycologist de Bary was the first to suggest that Chrysomyxa abietis originated from a form living on the rhododendrons, and Barclay showed that such a form possibly occurred in the Himalaya. The discovery of the æcidial and teleuto stages both on R. campanulatum renders such a view at least highly probable.

GYMNOSPORANGIUM CUNNINGHAMIANUM, BARCLAY.

One of the commoner rusts in Mussoorie is an Æcidium on Pyrus Pashia, the Himalayan wild pear, which is conspicuous on the

FIG. 5.—GYMNOSPORANGIUM CUNNINGHAMIANUM, TELEUTO FORM ON THE CYPRESS.

older leaves during the hot-weather months, in and around the station. The affected leaves bear orange-red patches, which may be half an inch in diameter on the upper surface.

On these spermagonia are formed, showing as tiny black dots, while the corresponding part of the lower surface bears little tubular Æcidia from one to two millimeters long.

The species also occurs at Simla, where its life-history was followed by Barclay. Its further development occurs on the Himalayan cypress, Cupressus torulosa.

After infection by æcidiospores from Pyrus Pashia the cypress develops teleutospore beds at the infected part, either on the branches or green twigs.

These beds are hemispherical or elongated, dark brown, bodies which during moist weather swell up enormously into gelatinous masses; later on they become yellowish in colour from the formation of sporidia on promycelia given out by the germinating teleutospores. By sowing the sporidia Barclay caused first spermagonia and then Æcidia to appear on the leaves of Pyrus Pashia.

In June 1904, Rai Sahib U. Kanji Lal, Vernacular Instructor at the Imperial Forest School, sent me some specimens of this fungus on cypress seedlings, and wrote that it was doing much harm in Jaunsar to young trees, especially those planted. Some of the seedlings sent were evidently dead from the effects of the parasite.

A European ally of this species, known as Gymnosporangium Sabinæ, is found on the juniper in the teleuto stage and on the pear tree in the æcidial stage. It causes much damage to the latter, but the destruction of the juniper trees in the neighbourhood of the orchards has, in several cases, led to the disappearance of the disease.

In Jaunsar it is possible that something of the same sort might be attempted wherever the cypress plantations are being much injured by this fungus. Removal of Pyrus Pashia for some distance around would probably lead to a considerable reduction in the cypress parasite in a few years.

PERIDERMIUM THOMSONI BERK. AND BARCLAYELLA DEFORMANS DIET.

A fungus attack, of which two forms were found on the Himalayan spruce, Picea Morinda (Abies Smithiana), was described

by Barclay in the *Journal of the Asiatic Society of Bengal* in 1886. The name Æcidium (Peridermium) Thomsoni was given to the fungus on the assumption of its identity with a species found in Sikkim by Hooker and described in the *Gardener's Chronicle* in 1852. The first of the forms described by Barclay had been previously referred to Peridermium acicolum by Cooke from specimens received from Dalhousie, in 1877. The same author received the second form from Mahasu, Simla, about the same time and referred it to P. Thomsoni (*Indian Forester*, Vol. III, p. 88). Both forms were, however, as above mentioned, taken by Barclay as stages of the one fungus, Peridermium Thomsoni, the first as the æcidial and the second as the uredo stage. Later on Professor Dietel, to whom specimens were sent, found that the latter was really a teleuto form, and referred it to a new genus Barclayella, of which it is the type and only known species. This view was accepted by Barclay, and the genetic connection of the two forms was left doubtful awaiting experimental investigation which has not been attempted so far.

It is common in the Himalaya from Mussoorie to Simla, and probably as far west as the Kurram valley of the Afghanistan frontier. I have received specimens at different times from Messrs. Oliver and MacIntosh, of the Imperial Forest Service, from Jaunsar.

The æcidial stage (Peridermium Thomsoni) as described by Barclay is conspicuous on account of its colour and of the drooping habit assumed by the affected shoots. Every needle of certain shoots is attacked, and instead of standing out stiffly from the stem they lie close together embracing it. Shoots of the current season's growth only appear to show it. Those attacked are usually considerably longer than the unaffected. Both stem and needles are yellow in colour and the older specimens are much thickened and curved.

Spermagonia appear towards the tip of the needles as little dark points uniformly distributed on the surface. The Æcidia are produced at a later period in two rows on the upper surface of the needles. At first they are pale red, but later on are reddish

orange. They are long flat bodies formed by a colourless transparent membrane, containing æcidiospores.

The Barclayella is much commoner than the Peridermium, and is the only form which I have seen. A greater amount of deformity is produced on the affected shoots which, as before, appear to be always of the current year's growth. They are stunted, thickened and densely covered with curved needles, having at a distance an orange-red colour. Instead of forming

FIG. 6.—BARCLAYELLA DEFORMANS ON THE SPRUCE.

two rows of isolated prominent spore-cases the teleutospores occupy two continuous flattened beds on the upper surface and two rows of smaller ones below. When young the whole emits a disagreeable odour.

One of the specimens sent me by Mr. MacIntosh in 1904 showed this form on the cones, in which position it has not previously been mentioned. The scales were attacked and some of them were deformed and stood out from the cone. Others such as that shown in the figure were unaltered in shape. The teleuto beds occurred on the dorsal (outer) surface of the scale in one or more raised reddish bands.

PERIDERMIUM PICEÆ BARCLAY.

The Himalayan spruce bears yet another rust, which I have received from Mr. Oliver from Jaunsar. This is the Peridermium piceæ described by Barclay.

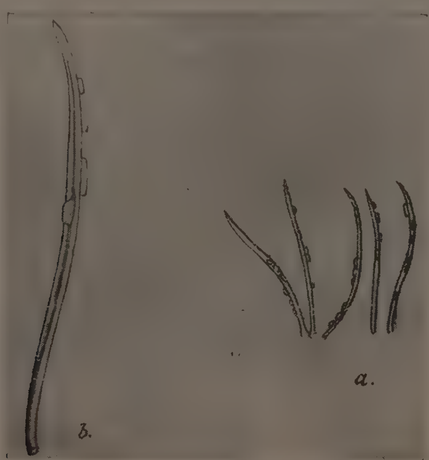

FIG. 7.—PERIDERMIUM PICEAE ON THE SPRUCE—a NATURAL SIZE; b MAGNIFIED THREE TIMES.

The æcidial (Peridermium) stage alone is known. It appears as long narrow spore-cases arranged along the upper surface of the affected needles somewhat irregularly and not in two rows as in Peridermium Thomsoni. The needles are turned yellow, and, as before, terminal shoots of the current year's growth

FIG. 8—PERIDERMIUM COMPLANATUM ON PINUS LONGIFOLIA.

are attacked. There is little deformity produced, but the presence of the parasite is revealed even at a distance by the orange-yellow patches scattered throughout the tree.

Mr. Oliver informed me that he had seen trees in Chakrata Cantonment in 1902 dying or dead from the effects of this fungus. This was due to the loss of all infected needles in 1901, when the attack was very severe. The trees were so weakened in consequence that they were unable to make new shoots or only put out feeble ones. None of the conifer rusts in the Himalaya have been hitherto described causing such damage as this.

PERIDERMIUM COMPLANATUM BARCLAY

I have received this species on Pinus longifolia from Simla, where it was described by Barclay, from Mr. Wroughton, I. F. S., and also from Palampur in the Kangra Valley collected by Mr. I. H. Burkill.

It resembles that last described except that the spore-cases are larger and are usually on the lateral or under surfaces of the needles. The attacked parts of the latter lose their colour, but the general effect of the fungus on the health of the tree appears to be slight. In Simla Barclay noticed that two crops are usually borne, one in November and the other, much more abundant, from February on to May. The former usually has spermagonia scattered irregularly over the surface of the needles while the latter has none.

A form (var. corticola) also occurs on the bark, where it does more harm than on the needles.

PERIDERMIUM BREVIUS BARCLAY.

This rust occurs commonly on Pinus excelsa in the same region as the last. It begins to appear according to Barclay about April in Simla, only one crop being produced. On the whole it resembles Peridermium complanatum, but the spore-cases are distinctly smaller. I have received it from Jaunsar.

PERIDERMIUM CEDRI BARCLAY.

A rare Æcidial form was found in 1884 on deodar in the Sutlej Valley, where a severe attack was observed on a few trees. Some needles only of each rosette were affected and curved downward. Numerous small Æcidia burst out on the upper surface without any accompanying discolouration. I have not seen this species.

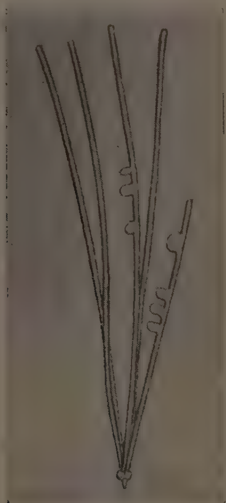

FIG. 6.—PERIDERMIUM BREVIUS ON PINUS EXCELSA.

PERIDERMIUM EPHEDRÆ COOKE.

I have received this species on Ephedra vulgaris collected in Karamba, Jaunsar, by Mr. Hole, I. F. S., in May, 1904. It is the only known member of the genus outside the Coniferæ.

The young shoots and leaves are attacked, the former bearing Æcidia and the latter numerous very prominent spermagonia. Considerable thickening of the shoots occurs, and from the specimens received it appears as if the number of these

is augmented and a sort of witch's broom deformity of the attacked branch induced.

The Æcidia appear all round the shoot as more or less cylindrical or bladder-like spore-cases containing orange-yellow spores.

FIG. 10.—PERIDERMIUM EPHEDRÆ ON EPHEDRA VULGARIS.

As in the case of the other Peridermia mentioned, no further stage is known. The species has previously been recorded on Ephedra antisiphylitica and californica from California and Texas.

THE BARBERRY RUSTS.

The classical example and the first known of the power of changing hosts (heterœcism) in the rust fungi is that of the black rust of cereals, Puccinia graminis. About 90 years ago a Danish schoolmaster named Scholer discovered that the dust in the cluster cups (Æcidia) of the common barberry was able to induce Puccinia graminis when shaken on rye. From that small beginning the study of the cereal rusts, those most destructive of all known fungus diseases, has been built up. Of late years the opinion has grown with many observers that the stage of the disease passed on the barberry may be dispensed with, and that the uredo and teleuto stages may appear year after year on corn without any intervening æcidial stage.

In India it is certain that this is the case. The last few years' observations have shown that Puccinia graminis is one of the commonest rusts in the central areas of India. The barberry, on the other hand, is confined to the higher mountains—the Himalaya and one or two other high ranges or peaks. Last year (1904) Puccinia graminis was found in every wheat field in places over 600 miles from the nearest barberry, a distance through which it is absurd to suppose that æcidiospores could be carried by the wind in any quantity. It is almost equally certain that no other plant occurs in these areas which replaces the barberry as a host of the Æcidium. The statement often repeated that the cereal rusts are largely caused by the leaf fungi of the Himalayan forests is therefore devoid of foundation.

Even the study of the barberry Æcidia themselves shows how little they can be called into question in this connection. For the true Æcidium Berberidis of the cereal black rust is a species whose range in the Himalaya is restricted. So far as present investigations tell it does not appear east of Simla. Around Simla it undoubtedly occurs on Berberis Lycium, and probably also on B. coriaria Royle, B. aristata D. C., and a species which has been doubtfully referred to B. umbellata Walt. It probably also occurs on B. vulgaris to the west of Simla, where alone this species is found.

The odd thing about this is that it is precisely at the only part of the Himalayan range where Æcidium Berberidis is

known to occur that black rust is extremely rare on cereals. In many years' search Barclay only once found it on wheat near Simla. It is, however, common on a wild grass, and with sporidia

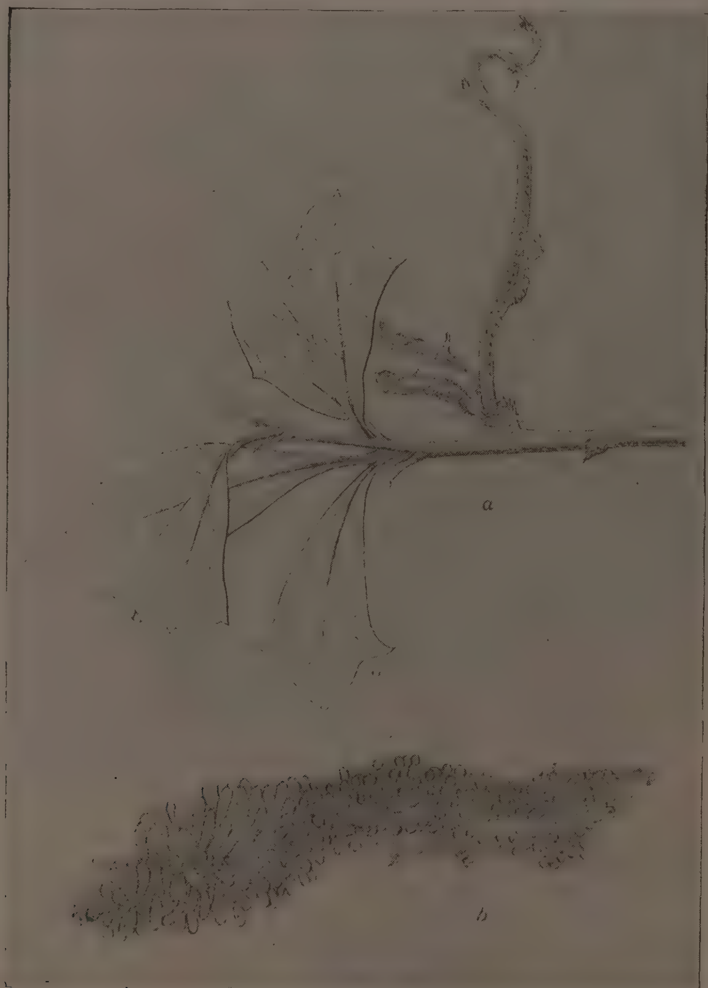

FIG. 11.—ÆCIDIUM MONTANUM ON BERBERIS LYCIUM. *a* DEFORMED SHOOT TURNED VERTICALLY UPWARDS (NAT. SIZE); *b* A LEAF BEARING ÆCIDIA (MAG. 4 TIMES).

from this Barclay succeeded in producing the Æcidium on B. Lycium. The only conclusion to be drawn is that the form found on the wild grass is a specialised form, which neither in its uredo nor in its æcidial stage can pass to the cereals. Hence even where the Æcidium is found its influence on the rusting of cereals is slight. A number of similar cases of this specialisation or splitting up of a parasite into races each confined to one variety of host are now known.

East of Simla Æcidium Berberidis is replaced by a second species of much interest. I have received it from several Forest officers from Jaunsar on B. coriaria, B. aristata, and B. Lycium, and it is abundant around Mussoorie. It is at once distinguished from the other by the peculiar deformity of the affected branches. A witch's-broom formation is induced on attacked parts, sometimes involving as much as half the bush. All the new shoots show negative geotropism or a tendency to grow vertically upwards. The Æcidia are found on small deformed leaves surrounding the buds or on specially modified shoots arising from the latter. These shoots are soft, blackish and curiously twisted in many cases and bear only spines or small, often deformed, leaves. The æcidial cups are formed on the under surface only of the leaves, but are scattered irregularly on the shoots. The floral peduncles are sometimes attacked and also some nearly normal shoots, which are, however, blackened over the area which bears the parasite. All the deformed parts contain a perennial mycelium in the interior of the tissues from the influence, of which no doubt the new growth shows its peculiar characters.

A second form, confined to the leaves, is also found, and from its characters seems to arise from infection anew by spores, and not from the perennial mycelium. Fully developed normal leaves are attached, the fungus producing large reddish or bright scarlet patches on the upper surface, and numerous very long tubular Æcidia below. Little deformity results, at the most a puckering of the leaves.

Intermediate forms between the two extremes described are frequent. Sometimes from a rosette of the stunted deformed leaves of the first variety a few normal leaves may arise, some of which have large patches of the second kind of attack. The

appearance strongly suggests a secondary infection of normally developed leaves either by the æcidiospores themselves or by sporidia from another host bearing the teleutospores. A second host is, however, unknown.

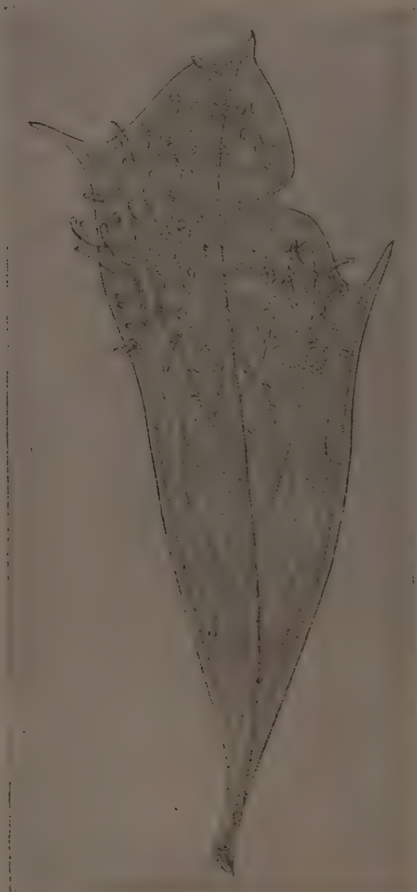

FIG. 12.—ÆCIDIUM MONTANUM ON A NORMAL LEAF OF BERBERIS LYCIUM (ENLARGED).

The first form is found from May until the cold weather, and perhaps continues during the latter, while the form on normal

leaves appears in June and July. Experiments have shown that neither form can infect cereals.

The influence of the parasite on the host may be summarised as follows : Dwarf shoots are produced at the nodes of a branch either as a result of infection from a perennial mycelium below or from new infection of the undeveloped bud by spores. These are formed during a considerable part of the year. Small deformed leaves arise on them, the internodes being much shortened, while the axis is thickened. As a result a cylindrical formation about half an inch in length, densely crowded with scales and minute fungus-bearing leaves, is produced. The leaves then fall, leaving the persistent scales while new buds may be formed in the axils of the fallen leaves. At the same time the peculiar succulent Æcidia-bearing shoots referred to above arise either in prolongation of the main axis of the dwarf shoot or from a lateral bud. Sometimes the whole of this, which may be 6 or 8 inches in length, is a spore-bearing organ, sometimes a part only; it is not uncommon also to find that the lower part alone bears the fungus while the upper has grown on into a harder thorny shoot approaching the character of a normal one. Leaves may be formed on this prolongation, but they are usually small, while the part which bears Æcidia is as a rule devoid of leaves or, if provided with any, they are deformed Æcidia-bearing ones. The portion of the shoot on which the fungus is found fructifying is always more or less blackened and rounded, usually hypertrophied, while the normal shoots are covered with a greyish bark and are angular. Normally developed leaves can also be attacked and produce large Æcidial patches unattended by deformity. Sometimes bushes are found with only this leaf form unaccompanied by any witch's-brooms.

In a section of one of the modified shoots bearing the Æcidia the perennial mycelium may be very easily detected. All the tissues are affected, with the possible exception of the cambium. The hyphæ run in the walls and intercellular spaces. Their contents frequently show yellow oil-drops. Haustoria for food aquirement are simple or branched finger-like processes, which appear to be sometimes covered with a protrusion of the cell-wall such as

is found in the haustoria of the Erysipheæ. Hypertrophy is slight and is chiefly found in the dwarf shoots which arise from infected buds and grow as short thick axes crowded with minute leaves.

Three fungi are known on species of barberry in other countries resembling this. One, Æcidium Magellanicum Berk., was found on B. ilicifolia in Terra del Fuego. Its Æcidia are found often on the petioles. Another, Æcidium graveolens Shuttlew., is connected with a Puccinia on Arrhenatherum in Europe and produces a complex and constantly increasing deformity while the Æcidia are sometimes found on the upper surfaces of the leaves. The third is Æcidium Jacobsthalii Henrici Magnus, which appears to have no spermagonia and to produce considerable thickening of the branches. Its æcidial cups are also short. The Himalayan species cannot be identified with any of these, and I have called it Æcidium montanum. Its diagnosis is as follows :—

Æcidium montanum Butl. n. sp. Maculæ absent or brilliant crimson with a black centre on the upper surface of the leaf and pale red below; spermagonia scattered on deformed shoots and leaves, or crowded in the black centre of the maculæ, chiefly epiphyllous but also hypophyllous in a group in the centre of the æcidia, black, sunken, flask-shaped, broader than deep, 65 micro-millimeters deep below the epidermis, 120 m. mm. broad, paraphyses 3 m. mm. broard, projecting in a stiff bundle from the mouth to 50—75 m. mm. above the surface.; spermatia minute, set free with mucus ; æcidia numerous and crowded on the whole of the under surface of the leaves or on patches ¼ to ¾ in. in diameter; pseudoperidium elongated to 4 mm. on the underformed leaves rarely more than 2 mm. on the witch's-brooms, orange below, whitish above ; æcidiospores orange, irregularly globose, ovoid or angular, 17-35 × 17-29 (average 19 × 23) m. mm. in diameter, epispore finely wrinkled.

On Berberis Lycium Royle, B. coriaria Royle, and B. aristata D.C. in the N.-W. Himalaya.

PUCCINIA DROOGENSIS N. SP.

In the Niligri Hills Berberis aristata was much rusted in 1904. The rust, however, differed from those described above, for, while

the uredo and teleuto forms were abundant on the leaves, I could not find any Æcidia. Even if Æcidium Berberidis should occur on these hills it can be of but little economic importance, for wheat cultivation is not common in South India.

The species does not agree with any already described, and I have named it Puccinia droogensis. Its diagnosis is as follows:—

Puccinia droogensis n. sp. Uredosori amphigenous, sparse, small, long covered with the epidermis, yellow, in irregular maculæ

FIG. 13.—PUCCINIA DROOGENSIS ON BERBERIS ARISTATA.
a UREDO STAGE; *b* TELEUTO STAGE.

pale with a red centre on the upper surface of the leaves; uredospores long-elliptical or clubshaped, yellow, 15-21 × 27-42 m. mm. in diameter, epispore up to 3 m. mm. thick with regular scattered spines; teleutosori on purple maculæ, amphigenous, pulvinate, confluent, irregular, ¼ to 1 m. mm. in diameter; teleutospores elliptical, both ends rounded, constricted at the septum, brown, 30-45 × 18-24 m. mm. in diameter, epispore very thick and marked with tubercles arranged in series.

On Berberis aristata D. C. in the Droog, Nilgiri Hills, altitude 6,000 ft., October 1904.

GAMBLEOLA CORNUTA MASSEE.

Berberis or Mahonia nepalensis bears a remarkable rust in the Mussoorie and Jaunsar Himalayas. This is the species from which Mr. Massee of Kew derived the new genus Gambleola, named in honour of its discoverer, Mr. J. S. Gamble, F. R. S., of the Indian Forest Service. The species is known as Gambleola

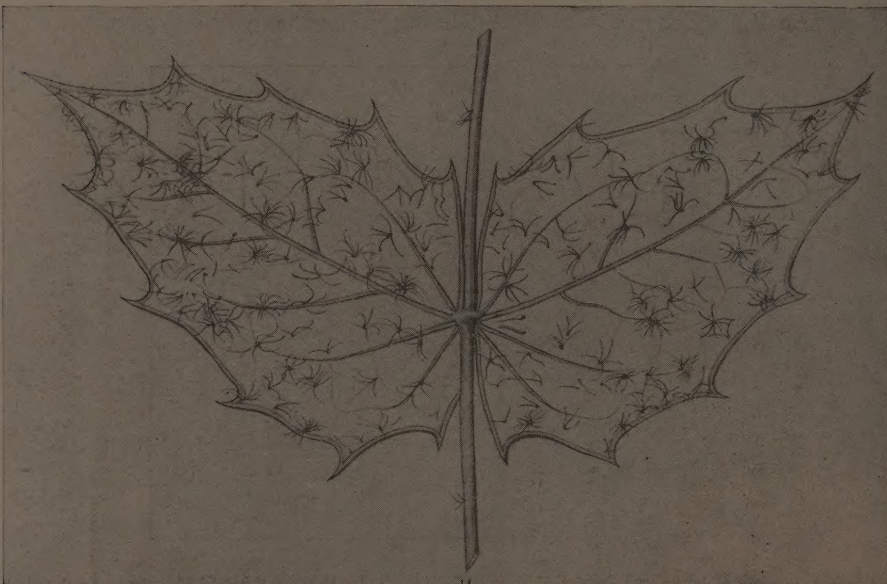

FIG. 14.—GAMBLEOLA CORNUTA ON BERBERIS NEPALENSIS.

cornuta. It appears in the form of long black wavy hairs grouped in clusters on the under surface of the leaves and sometimes also on the twigs. Each hair consists of many chains of two-celled teleutospores adhering closely to one another in the chain and also to adjoining chains. No other spore form is known, and it would be a matter of extreme interest to follow out its development and ascertain its life-history. This must be left to those fortunate enough to live near the haunts of Berberis nepalensis; but there are few pursuits of more absorbing interest than to trace in such fungi as this the varied changes of form, associated as they so often are with an alternation of hosts.